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THE SYMMETRY OF TIME IN PHYSICS*

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A FEW years ago I presented[1] the outline of a theory of light which required a radical change in our ideas of temporal causality. Instead of assuming the time-honored unidirectional causality, in which cause inevitably precedes effect, it proved necessary to assume that the present phenomena of a system are determined no more by the past states of the system than by its future states. Several recent developments in physics make this assumption seem less startling now than then; indeed I am fully convinced that there is no other way in which we can account for the known phenomena of light. Moreover, new discoveries in wave mechanics indicate that any conclusions concerning the emission of light must be extended to the emission of every kind of material particle.

By such considerations I was led, in "The Anatomy of Science," to examine with some care the meaning of time, as the word is used in physical science. It often happens that a common concept of daily life may profitably be simplified or refined when it is to be employed in a single branch of science. In studying the vastly complex phenomena of nature, as they come to us through our sense impressions, we could make little headway did we not segregate and idealize certain groups of like phenomena for the purpose of special study. Such segregations define the several branches of science, of which one of the most highly specialized and idealized is physics. Only a few types of phenomena are included within its bounds, and in its study we consciously abstain from employing many of our commonest ideas, such as purpose, goodness, beauty. In the physical sciences a statue of Praxiteles is a certain mass of crystalline calcium carbonate; the shape may or may not be mentioned. It was the scientific arrogance of a previous age that called a law of physics a law of nature. To speak so is to forget the bounds that we have ourselves established.

* Address given on the occasion of the presentation of the gold medal of the Society of Arts and Sciences, New York, April 17, 1930.

[1] Nature, 117: 236, 1926.

It is therefore evident that such notions as those of time and space may be given a simpler significance when we are dealing with a single science than when we are concerned with the complexities of natural occurrences in general. Our common idea of time is notably unidirectional, but this is largely due to the phenomena of consciousness and memory. Was Newton right in deliberately introducing into physics this common idea of the *flow* of time? Surely in one great branch of physics which we owe to his genius, the mechanics of conservative systems, it has long been recognized that there is need for nothing more than the simple idea of symmetrical time, which makes no distinction between past and future.

These two ideas of time, the unidirectional and the symmetrical, I have for brevity called "one-way" and "two-way" time. In going from the very simple science of mechanics to the very complex science of psychology, we must change from two-way to one-way time. It is important to inquire where this transition comes, and whether two-way time suffices for some parts of physics while one-way time is needed for the remainder.

The thesis that I announced earlier, and now wish to elaborate, is that throughout the sciences of physics and chemistry, symmetrical or two-way time everywhere suffices. As a philosophic speculation this view has received some attention, but I shall be much disappointed if it can not also be accepted as the statement of a law of physics, of exceptional scope and power, directly applicable to the solution of many classical and modern problems of physics.

Let us therefore review the several great branches of physics in the light of this thesis of symmetrical time. These branches are mechanics, thermodynamics, theory of radiation and electromagnetics. We shall see that nearly everywhere the physicist has purged from his science the use of one-way time, as though aware that this idea introduces an anthropomorphic element, alien to the ideals of physics. Nevertheless, in several important cases unidirectional time and unidirectional causality have been invoked, but always, as we shall proceed to show, in support of some false doctrine.

MECHANICS

Mechanics includes the still more limited science of kinematics. For a century or more there have been attempts,[2] culminating in the brilliant work of Minkowski, to make kinematics a branch of geometry. It was the hope, now fulfilled, that time could be combined with space into a four-dimensional manifold, of which the geometry should reproduce the science of kinematics.

[2] *E.g.*, Fechner (Kleine Schriften), "Der Raum hat vier Dimensionen."

To lighten the discussion, let us imagine one of these precursors of Minkowski, whom we may call Dr. X. In one of his note books we might read, "If this geometrical view of kinematics is correct there must be no distinction of past and future. It would be absurd in Euclidean geometry to prove a theorem by means of a diagram, and then to claim that the theorem becomes invalid if the diagram is turned upside down. Likewise there is no up or down in the four-dimensional geometry of kinematics."

It was also the belief of Dr. X that the rest of mechanics could in turn be identified with a still more comprehensive geometry, and it seemed to him that this view received some corroboration in the fact that the mechanics of conservative systems requires no dissymmetry of time. All the equations of mechanics are equally valid when t is replaced by $-t$. The chance of error is the same in calculating an eclipse of a thousand years ago or of a thousand years hence.

Becoming even bolder, this eager speculator hoped that not only mechanics but all physics might eventually be reduced to a geometry. He wrote, "If this belief be correct, Newton's idea of a flow of time has no place in physics. Until I see strong evidence to the contrary, I shall maintain this to be a basic law of physics, that all rules which are obtained from a study of physical processes hold with equal validity if these processes are reversed in time. Every equation and every explanation used in physics must be compatible with the symmetry of time. Thus we can no longer regard effect as subsequent to cause. If we think of the present as pushed into existence by the past, we must in precisely the same sense think of it as pulled into existence by the future."

THERMODYNAMICS

The second law of thermodynamics was a source of uneasiness to Dr. X. Recognizing the importance of its consequences, he still objected to the statement of Clausius, namely, that in any system left to itself the entropy increases steadily toward a maximum. This statement is in direct defiance to the law of the symmetry of time. Therefore to Dr. X it was a great satisfaction to read in a paper of Willard Gibbs that "the impossibility of an uncompensated decrease of entropy seems to be reduced to an improbability"; and later to follow the development of this thesis by Boltzmann until near the end of the famous lectures on "Gastheorie" he found Boltzmann saying, "Hence, for the universe, both directions of time are indistinguishable, as in space there is no up or down."

Boltzmann's qualifications of this statement seemed unnecessary to Dr. X, who now definitely included thermodynamics among those branches of physics which require symmetrical time only. In his note

book we read, "The statistical interpretation of thermodynamics offered by Gibbs and Boltzmann affords for the first time an understanding of entropy. The process irreversible in time does not exist. This corollary of the law of symmetry in time itself leads to further important consequences. Thence we may prove to those who are still skeptical the atomic structure of matter, as follows: if we imagine two continuous media to diffuse into one another, such a diffusion would in principle be a phenomenon which by no physical means could be reversed, but if two streams composed of discrete particles should diffuse, then, although it might be a matter of great difficulty to recapture the particles and restore each to its own kind, yet in principle the process is reversible and indeed, according to Boltzmann, the separation will occur spontaneously if the system be left to itself for a sufficiently long period."

Dr. X adds a remark of much subtlety. "While we recognize the particulate nature of matter, we allow each particle to have a position and a velocity chosen from a whole continuum of possible values. Thus while we claim that an isolated system repeatedly returns nearly to its initial condition, we can not say that it returns exactly to that condition. If we start with a number of molecules all moving in precisely the same direction, we can not claim that after some disturbance they ever again move quite parallel to one another. This implies a sort of irreversibility, and while I am not sure that it is a contradiction to symmetrical time, I confess that I should be better satisfied if we could claim the exact recurrence of an initial state."

It is a pity that Dr. X did not live to see the universal acceptance of quantum theory, which assigns to an isolated system not an infinite continuum of states, but a finite number of discrete states. Thus every particular state exactly recurs within finite time. This modern picture is far simpler than that of Boltzmann, especially as we are going to see that each particular state occurs as often as every other. Hence molecular statistics furnishes quite elementary problems in the theory of probability, like the tossing of coins or the shuffling of cards.

In the main, however, the problems of thermodynamics to-day are not far different from those discussed by Boltzmann and Dr. X. In the note book of the latter we read, "The earth is constantly receiving energy from the sun, and in consequence water is continuously flowing over Niagara Falls, but these descriptive statements can not be called laws of physics. When we turn to the processes studied in the laboratory we find that when a hot and cold body are brought together, it is almost certain that the two temperatures will become equalized until no discernible difference remains. If we mix two mutually soluble liquids, we may expect the concentration to become nearly uniform. I have learned that it is possible to perform an operation upon the brains of mice so that they respond to no external stimuli, but can still run aimlessly about. If a large number of these mice are placed in one end of a box, that end is now heavier than the other; but this distinction rapidly disappears as the mice, in their random movements, cover with greater uniformity the bottom of the box, so that we may no longer discern any tendency of the box in one direction or the other. I claim that in all these cases there is no phenomenon irreversible in time, and indeed nothing more formidable occurs than in the proverbial case of a needle dropped into a haystack."

Before analyzing further these problems, we may consider a very interesting discussion of one-way time by Professor Eddington, in "The Nature of the Physical World." He arrives at a compromise, first by stating that one-way time does not occur in physics outside of thermodynamics, and then by reducing the principle of the increase of entropy from a "primary" to a "secondary" law, which does not prevent him, however, from deducing therefrom a "running down of the universe." To this compromise I can not agree. The first statement will be answered by the cases which will be discussed in the following sections, and the second can not be regarded as consistent with the new conception of thermodynamics.

We must be cautious about extending to the whole cosmos the rules which we have obtained from limited experiments in our small laboratories. The chance of obtaining valid results from such an extrapolation is very small, but it can be made in a purely formal way. If the universe is finite, as is now frequently supposed, then the formal application of our existing ideas of thermodynamics and statistics leads directly to the following statement: The precise present state of the universe has occurred in the past and will recur in the future, and in each case within finite time. Whether the universe actually is running down is, of course, another matter. All we can say is that such an assumption obtains no support from thermodynamics.

Let us, however, turn from the behavior of the universe, about which we know almost nothing, to the phenomena of the laboratory, about which we know a little more. Even in this limited domain it is going to be difficult enough to persuade ourselves that such a phenomenon as an explosion is wholly compatible with the thesis of symmetrical time. If a statement runs counter to a fixed habit of thought which has become nearly instinctive, it may be accepted by many, but believed by few. The use of one-way time

has become second nature to us, and to oust from the mind all its implications, even when we set ourselves to do so, is no easy task. Nevertheless, perhaps we can make this task easier if we dig up by the roots and examine with all care this thing that we call an irreversible process.

We must begin by guarding against two human frailties—the feeling that there is some real distinction between familiar and unfamiliar things, and the fear of large numbers. Let us illustrate by means of a pack of cards, and at first a very small pack, say the ace, two, three and four of spades. There are twenty-four possible distributions, such as 1, 2, 3, 4; 4, 2, 1, 3; 4, 3, 2, 1, and so on. Of these the first and third are a little more easily described and remembered than the other twenty-two, which for this reason we call nondescript, but this is only a question of familiarity. A whist player would think of the arrangement, 1, 4, 3, 2, and there is no one of the twenty-four arrangements which might not be particularly significant in some other card game.

If our attention has been drawn to one particular distribution, we remark upon it when it results from random shuffling; but on the average each distribution, whether or not it has been favored by our attention, will turn up once in twenty-four times. If we now take a pack of fifty-two cards, the familiar, or easily described, distributions are relatively rare compared with all the nondescript arrangements, and if random shuffling should give the exact distribution of the pack as it comes from the manufacturer it would seem almost a miracle; yet we can say with the same certainty as before that any one particular distribution will, on the average, occur once in 52! times. The rules of arithmetic are the same for large numbers as for small.

There is no such thing as a well-shuffled pack, except with reference to certain familiar sequences. If the distribution does not closely resemble some familiar sequence, we might call it well shuffled. There is, however, another sense in which the idea of shuffling is of fundamental significance. If we examine a particular distribution and remember the sequence of the cards, afterwards the pack is said to be well shuffled when our remembrance of the previous distribution no longer aids us in guessing what a new distribution will be. This distinction between a known distribution and an entirely unknown one will prove to be fundamental in our study of the corresponding problems of thermodynamics.

Turning now to the irreversible thermodynamic process, we shall choose an illustration which is not quite so complicated as an explosion, but involves all essentials. A chemist has spent days in preparing a flask of nearly pure alcohol. This he places in a water bath, and then by accident the flask overturns and the alcohol diffuses through the water. His disappointment is in no way allayed by the fact that none of his material is really lost, nor by the belief that ultimately the molecules of alcohol will accidentally come together to give once more a nearly pure sample. That the chemist would be obliged to wait an unconscionable time for this chance restoration must be given no weight. If it occurred every ten minutes, the principle would be the same. It would still be necessary for him to devise rapid analytical methods to ascertain just when the fortunate event occurred. There is no question but that the accident has involved an element of *loss* which typifies the irreversible process (which is also spoken of as a process of dissipation, or degradation), but we shall see that this loss in no way implies a dissymmetry of time, nor indeed that it has any temporal implications whatever.

Without losing any of the characteristics of the reversible process, we may next examine one of the simplest of systems. Suppose that we have a cylinder closed at each end, and with a middle wall provided with a shutter. In this cylinder are one molecule each of three different gases, A, B and C, and the cylinder is in a thermostat at temperature T. In dealing with the individual molecules we are perhaps arrogating to ourselves the privileges of Maxwell's demon; but in recent years, if I may say so without offense, physicists have become demons.

Regarding each molecule, we shall ask only whether it is in the right or the left half of the cylinder. Obviously eight distributions are possible, such as A and B on the left and C on the right; or B on the left and A and C on the right. According to our ordinary assumptions, each of these distributions is equally probable, or, in other words, the system averages to be in each distribution one eighth of the time. Moreover, each of the eight distributions can be easily described and remembered, so that we are not troubled by a large number of nondescript states. Each distribution occurs over and over, but in no particular order, and in these occurrences there is no trace of dissymmetry with respect to time—there is no "running-down" process here.

Yet we may have a typical irreversible process. Suppose that the shutter is closed so as to trap a particular distribution, say all three molecules on the left. We become familiar with this one distribution and wish to study it further, but accidentally the shutter is opened, and instead of the one distribution, we have all eight succeeding one another in a random way. This is a complete analogy to the overturn of the flask of alcohol. If we desire once more to obtain and keep the one distribution in which all the mole-

cules are on the left-hand side of the cylinder, we may exercise our prerogatives as Maxwell demons by closing the shutter from time to time and determining by spectroscopic means or otherwise which distribution is trapped. In about eight trials we shall obtain the desired result. Unless, however, there is in sentient beings the power to defy the second law of thermodynamics, we shall find that this method of obtaining the desired distribution requires at least as much work as the old-fashioned thermodynamical method of forcing the system into the particular distribution without the aid of demoniacal devices. This classical method consists in slowly pushing a piston from the extreme right of the cylinder as far as the middle wall. In this typical reversible process the work required to overcome the pressure of the three molecules is $3\ k\ T \ln 2 = k\ T \ln 8$. At the same time the entropy of the gas is diminished by $3\ k \ln 2$.

If we wish to obtain any other one of the particular distributions, from the general distribution, the same amount of work is required. Suppose the particular distribution desired is B on the left, A and C on the right. At the extreme left we have a piston permeable only to B, and at the extreme right a piston permeable only to A and C, and these pistons are moved slowly to the middle wall. We thus obtain the given distribution, and the sum of the work done upon the two pistons is $3\ k\ T \ln 2$. In every case, in passing from the general distribution to a particular known distribution, the gas loses entropy in the amount $3\ k \ln 2$. All these processes are completely reversible. If we start with any known distribution and let the proper pistons move outward from the center to the ends of the cylinder, we obtain the general distribution, the system does work in the amount $3\ k\ T \ln 2$, and the entropy of the gas increases by $3\ k \ln 2$.

The entropy of the general unknown distribution is greater than the entropy of any one known distribution by $3\ k \ln 2$. This, therefore, is the increase in entropy in the irreversible process which occurs when, after trapping any one *known* distribution, we open the shutter. It is evident, however, that the mere trapping of one distribution makes no change in the entropy, for the shutter may be made as frictionless as we please, and the mere act of opening or closing it will not change the entropy of the system. If we start with the shutter open, with all the eight distributions occurring one after another, and then close the shutter, the system is trapped in one distribution, but there is no change of entropy.

Whence we have now reached our most important conclusion. The increase in entropy comes when a *known* distribution goes over into an *unknown* distribution. The loss, which is characteristic of an irreversible process, is *loss of information.* In the simplest case, if we have one molecule which must be in one of two flasks, the entropy becomes less by $k \ln 2$, if we know which is the flask in which the molecule is trapped.

Gain in entropy always means loss of information, and nothing more. It is a subjective concept, but we can express it in its least subjective form, as follows. If, on a page, we read the description of a physicochemical system, together with certain data which help to specify the system, the entropy of the system is determined by these specifications. If any of the essential data are erased, the entropy becomes greater; if any essential data are added, the entropy becomes less. Nothing further is needed to show that the irreversible process neither implies one-way time, nor has any other temporal implications. Time is not one of the variables of pure thermodynamics.

THE THEORY OF RADIATION

The laws of optics are entirely symmetrical with respect to the emission and absorption of light. The whole science of optics leaves nothing to be desired with respect to symmetry in time. When time is considered reversed, the emitting and absorbing objects merely exchange rôles, but the optical laws remain unchanged. On the other hand, the physical theories concerning the radiation from a particle, which were for a long time current, introduced the idea of one-way time in a notable manner. Let us quote once more from the note book of Dr. X.

"It has always been conceived that a particle which has been set in vibration, perhaps by collision with another particle, dissipates its energy in a continuous expanding spherical shell, every part of which moves steadily out into space until it meets an absorbing body. Since the energy all comes from the vibrational energy of one particle, the whole is regarded as a unitary process, although those parts of the shell of energy which meet neighboring objects may be absorbed within a very small fraction of a second, while other portions may travel years before they meet an absorbing object. The exact physical reversal of such a process is quite unthinkable. We should be obliged to imagine some prearrangement whereby each of a number of bodies far and near would, at the appropriate time and in the right direction, send out its quota of energy, all of which in the neighborhood of the absorbing particle would coalesce into a continuous spherical shell. As a rare event it might by chance occur that something approximating to this picture would be observed, but in no case could an exact reversal of the assumed process of radiation be found.

"The emission of a continuous spherical shell of

energy is essentially irreversible in time, like the diffusion of continuous media which we have previously discussed. But we shall still be in trouble even if we assume that the energy radiating from a particle does not spread as a continuous shell, but goes to a limited number of other particles. Assume that a central particle emits energy to a number of other particles, and that its oscillations are damped as it loses energy, according to some simple law. The amounts of energy received by the several particles and the time of receipt are assumed to be causally connected, since the energy all flows from the one simply damped central atom.

"The exact temporal reverse either of this process or of this explanation is absurd. It would be necessary to imagine a central atom which receives energy from other atoms in such amounts and at such times as to increase continuously the oscillations of the central atom, according to a law exactly opposite to the law of damping; and we should be obliged to explain this phenomenon by saying that the amounts of energy emitted by the several particles, and the time of their emission, are all causally connected, by the fact that the energy is all to be received, and in a specified manner, by the central atom.

"After many considerations of this character I have come to the conclusion that the only process of radiation which can be harmonized with the symmetry of time is a process in which a single emitting particle at any one time sends its energy to only one receiving particle."

I think we may now agree that Dr. X was right and that if we are to assume the principle of symmetry in time, we are led irresistibly to a theory of radiation which has some of the characteristics of Einstein's theory of the light quantum. In particular we can not admit the possibility, now occasionally assumed, that in a single quantum process an atom may emit two photons to two separate atoms. Furthermore, in this theory of radiation we must assign to the emitting and to the absorbing atom equal and coordinate rôles with respect to the act of transmission of light, as I proposed in my former paper.

ELECTROMAGNETICS

Our friend Dr. X was eminently satisfied with the development of the theory of electricity and magnetism. He saw that the equations of Maxwell would be equally valid if time were reversed, and was therefore bewildered by Maxwell's deductions from these equations of a theory of radiation which, from his point of view, had all the faults of previous theories. How was it possible to obtain the old one-way theory of radiation from equations which involve nothing but symmetrical time? He did not see the full answer to this question until the development of the theory of *retarded potentials*. Then he realized that in the mathematical treatment of the problem two symmetrical solutions arose, of which one was arbitrarily discarded because it seemed inconsistent with common notions of causality.

In the whole history of physics this is the most remarkable example of the suppression by physicists of some of the consequences of their own equations, because they were not in accord with the old theory of unidirectional causality. We shall therefore attempt to analyze this problem, especially as this abstruse subject may be rendered quite simple by geometrical methods.

For this purpose Professor Wilson and I invented[3] the geometrical vector field. A vector field need not involve physical quantities such as momentum or force, but may be purely geometrical; for example, a line in space may serve to define any number of such vector fields. Thus we may, from every point in space, draw a vector along the perpendicular to the line, and with a magnitude proportional to the distance from the line.

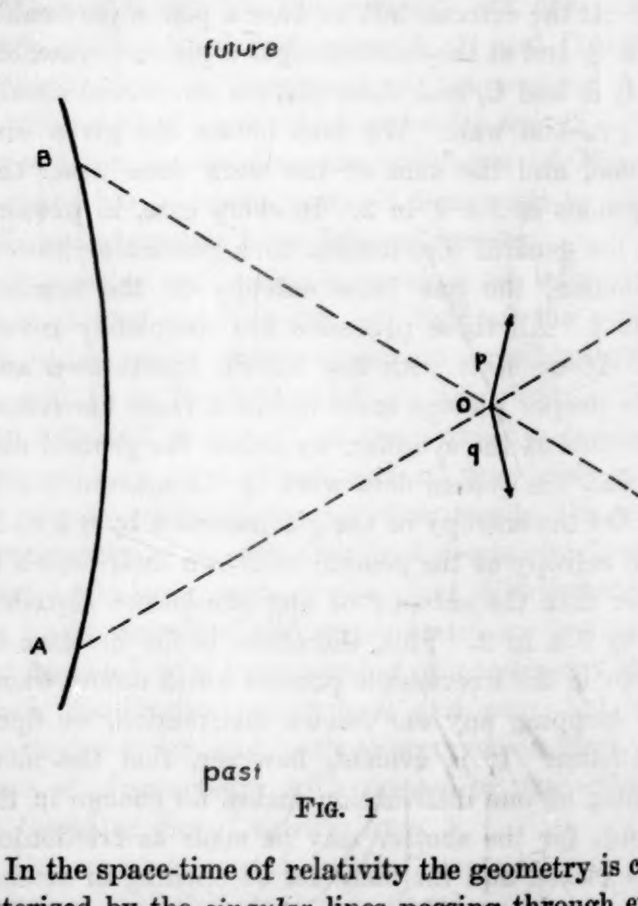


FIG. 1

In the space-time of relativity the geometry is characterized by the *singular* lines passing through every point, which are interpreted physically as light-paths. In the accompanying two-dimensional diagram they are represented for the point O by the dotted lines. In this geometry we set up the following vector field. Given any curve of the type AB, as the source of the field, then at any point O through which pass the singular lines OA and OB, the vector *p* is drawn

[3] *Proc. Amer. Acad.*, 48: 389, 1921.

upwards, parallel to the tangent of the curve at A, and with a magnitude which is the reciprocal of the distance from O to that tangent. The geometrical field thus set up has very remarkable properties. Our rules determine the variation of p in the neighborhood of O, and thus all its derivatives. The equations obtained are identical with all the complicated equations of the electromagnetic field produced by a moving and accelerated charge. This parallelism becomes an identity when we consider the curve AB as the locus in space-time of an electrical charge, and multiply the vector p by the magnitude of the charge. This vector, when projected upon a chosen time-axis, and upon the corresponding space, gives the scalar and the vector parts of the so-called retarded potential. It was so named because the influence of the charge at A was supposed to travel outward with the velocity of light and reach the point O at a later time.

Returning, however, to our geometry, we see that since there is no distinction between up and down, it is quite impossible to define the vector p without at the same time defining the vector q, which is drawn downward parallel to the curve at B. The projections of the vector q (multiplied by the charge) are quantities which have occasionally been studied under the name of *advanced potentials*. If they alone had been employed, the retarded potentials being discarded, we should have had an electromagnetic theory of light which would have been in equally good agreement with experimental facts, but in the interpretation of which we should have been obliged to regard the absorbing particle as the active agent, sucking in energy from all parts of space, in a spherical shell which contracts with the velocity of light.

As we now know, neither of these two electromagnetic theories is correct, and they can be used only as analogues; but in using such analogues we must hereafter give equal and symmetrical consideration to the retarded and to the advanced potentials; which means that in any theory of light we must consider the emitting and receiving agents as of coordinate importance. Thus, for example, if we wish to consider the probability that an atom X will emit a photon to an atom Y, and for this purpose imagine a virtual field produced by the particle X because of something analogous to its retarded potential, we must at the same time consider the particle Y as the seat of another virtual field of the advanced instead of the retarded type, and these two fields must be combined in a symmetrical manner to give the probability in question.

In recent months attempts have been made to extend quantum mechanics to the electromagnetic field, and here again the retarded potentials have been employed. We may safely predict that such attempts will not fully succeed until the retarded and advanced potentials are used simultaneously and symmetrically.

Applications to New Problems

We have seen that if science long ago had accepted the principle of symmetry in time, it would have eliminated the idea of unidirectional causality which has led to so many of the errors of classical physics. From this principle could have been deduced the atomic structure of matter and the newer thermodynamics. By its aid the flaws in the older theories of radiation and in the electromagnetic theory would have been seen. Moreover, the idea that light passes only from one particle to one particle, and that in this process the emitting and receiving atoms play coordinate parts, was directly derivable from the law of the symmetry of time. Let us now see whether there are new and unsettled problems which may be similarly solved.

Of the utmost importance to chemistry is the problem of reaction rates. Knowing only the state of equilibrium in a chemical reaction we know nothing of the rates of the individual reactions; but if we know the laws governing the rate of a reaction in both directions we may calculate the conditions of equilibrium. We now find that the complex problem of reaction rates may be reduced to the simpler problem of the transition probabilities between two elementary states. It will be a long time before many of these transition probabilities or intrinsic reaction rates can be calculated, but we shall see that there is one fundamental law that governs them.

When we say that we have chemical or thermal equilibrium, we mean that the average amount of each chemical substance (and also the number of particles of each species lying within a specified region, such as a region of energy), on the average remains constant. If, for example, substances A, B and C can change one into another the amount of each of these substances in equilibrium will not change, but thermodynamics alone tells us nothing of the paths by which they may go. For example, we might assume rapid processes from A to B, B to C and C to A, and slow processes for the reverse direction, A to C, C to B and B to A. There has, however, been a growing tendency to regard as impossible all such "cyclic equilibria." The principle was used in a limited way by Boltzmann, and was taken over in the quantum theory of the kinetics of gases. There was, however, a few years ago, a general disinclination to extend the principle to systems involving radiation. I believe I was the first to set up this principle[4] as a universal law in all physics and chemistry, applicable not only to chemical and physical proc-

[4] *Proc. Nat. Acad. Sci.*, 11: 179, 1925.

esses involving material substances, but also to processes involving light. I called it the principle of entire equilibrium. It has also been called the principle of microscopic reversibility and the principle of detailed balancing. It states that in equilibrium the rate of change along every detailed path is equal to the reverse rate.

Led to the formulation of this law by the idea of symmetry in time, which I was then beginning to develop, I remarked, "The law of entire equilibrium might have been called the law of reversibility to the last detail. If we should consider any one of the elementary processes which are occurring in a system at equilibrium, and could, let us say, obtain a moving-picture film for such a process, then this film reeled backward would present an equally accurate picture of a reverse process which is also occurring in the system and with equal frequency. Therefore in any system at equilibrium, time must lose the unidirectional character which plays so important a part in the development of the time concept. In a state of equilibrium there is no essential difference between backward and forward direction in time, or, in other words, there is complete symmetry with respect to past and future."

Indeed, we can readily see that any cyclic equilibrium would mean dissymmetry in time, for, suppose that in the case cited above we could say that the process occurring followed chiefly the route ABCAB . . . , then if time were reversed, we should obtain the opposite rule, namely that the main route would be ACBAC . . . .

Consider for any system the completely detailed quantum states designated as *a, b, c* . . . , the law of entire equilibrium states that the system changes from *a* to *b* as often as from *b* to *a*. Now the chance of a transition from *a* to *b* is proportional to the probability, p_a, of finding the system in *a* multiplied by an intrinsic probability, φ_{ab}, that when the system is in *a*, it will go over in a given time to *b*. The law of entire equilibrium therefore states that

$$p_a\varphi_{ab} = p_b\varphi_{ba} \tag{1}$$

Let us now examine these intrinsic probabilities, φ_{ab} and φ_{ba}. There seems at first sight nothing in the symmetry of time to restrict the values of these quantities. Supposing for the moment that these are the only two states, and assuming that, on the average, the system remains twice as long in the state *a* as in the state *b*, the same would be true if time were reversed. A moving-picture representing the successive changes would look the same if it were run in either direction. However, science can not rest content with such a statement regarding the intrinsic probabilities; it immediately inquires what physical quantities determine these probabilities.

According to the old idea of causality, the probability of a transition would be determined by the properties of the state which existed *before* the transition. In other words, the probability of the transition $a \rightarrow b$ would be some function of the properties of the state *a*, and the transition $b \rightarrow a$ would be the same function of the corresponding properties of the state *b*. Such a view is no longer permissible. If a transition depends upon the properties of the state preceding the transition, it must in equal measure depend upon the properties of the state following, so that φ_{ab} must be a symmetrical function of the properties of *a* and *b*. Since φ_{ba} must be taken as the same symmetrical function of the same properties, we obtain immediately the most fundamental law of physical and chemical processes,

$$\varphi_{ab} = \varphi_{ba} \tag{2}$$

This law stating the equality of direct and reverse transition probabilities has received no name, except in so far as it has occasionally been confused with the law stated in equation (1). We may call it the law of the mutuality of elementary processes, or, more simply, the mutuality principle. The name is intended to suggest the important fact that a transition in one direction and a transition in the opposite direction are not two physical entities, but one entity looked upon in two ways. Whatever we can say of one process, we can say of the other. We may think of a double arrow rather than of two arrows pointing in opposite directions. At present the law is best illustrated by some of the equations of quantum mechanics, such as the equations of Schrödinger in which transition probabilities are expressed as symmetrical functions of the "proper functions" of two states.

The law of mutuality holds for the elementary states, or, in other words, for the completely specified quantum states of a system. When a system is said to be in a condition which comprises a number of elementary states, the probability of a transition from one such condition to another depends not only upon the properties of the elementary states, but also upon their number. Thus, for example, if condition α comprises only one elementary state *a* and condition β comprises the two elementary states *b* and *c*, the probability of a transition $\alpha \rightarrow \beta$ is the sum of φ_{ab} and φ_{ba}, but if the system is in the condition β the probability of the reverse transition is not $\varphi_{ba} + \varphi_{ca}$ but is less, owing to the fact that when the system is in condition β it is in state *b or* state *c*, but not in both.

Generalizing, we may say that when we are dealing with a complicated chemical reaction in which a condition α goes into, or proceeds from, a condition β, and if we find that the specific reaction velocity is greater in the direction $\alpha \rightarrow \beta$ than in the direction $\beta \rightarrow \alpha$, it signifies that there are more elementary states comprised in the condition β than in the condition α.

By combining equations (1) and (2) we obtain a third law which is known as the equality of *a priori* probabilities and which, since it does not involve the element of time, we need discuss no further here. It is

$$p_a = p_b \tag{3}$$

These three laws, of which, in fact, the first and third are both derivable from the second, are the fundamental laws of quantum kinetics and quantum statistics. They are at present the most important deductions from the law of the symmetry of time.

It is remarkable that so many positive conclusions result from the negative statement that physics requires no one-way time, but more important conclusions have been derived from the similar negative statements that we can not have a perpetual motion machine and that we can not determine absolute velocities. Whether the new law will be successful in leading to new and unexpected conclusions remains to be seen. At least, if accepted, it will warn us away from certain lines of thought which involve one-way time. There is at present in the study of quantum mechanics and in some interpretations of Heisenberg's uncertainty principle a tendency to introduce anew the idea of unidirectional causality. I feel convinced that this is a retrograde tendency which may introduce new errors into science.

OBITUARY

SHOSABURO WATASÉ

AMERICAN zoologists of the older generation well remember the young Japanese zoologist who came to America in 1886, became Bruce Fellow in Zoology at the Johns Hopkins University, where he took his Ph.D. degree in 1890, and was successively attached to Whitman's Department in Clark University (1890–1892) and the University of Chicago (1892–1899) before his return to Japan. He was also a well-known figure at Woods Hole where he spent most of his summers in America from 1888 on. Few of the many Japanese who have begun their scientific careers in America identified themselves more closely with the country of their residence, attained such sympathetic and thorough understanding of its history and spirit, so loved its literature and that of old England, or obtained such mastery of its spoken and written language as Sho Watasé. His friends had ceased to regard him as foreign, and thought of him as a permanent acquisition, so apparently domiciled was he in American social and academic life, until his sudden decision to return to Japan and accept the chair of zoology in the University of Tokyo in 1899.

This was a total loss to American zoology, for he resumed the old way of his life as completely as he had abandoned it for over twelve years, and his only visits to America thereafter were two brief ones on scientific missions. His return to Japan cut short a line of work in which he had already obtained marked distinction, and thereafter the needs of Tokyo and Japan claimed his undivided allegiance. This little sketch of his life will serve to fill out the picture for those who knew him, and to shadow forth a notable life to those who did not have this privilege.

Watasé was born in Tokyo, November, 1862, and there also he died March 8, 1929. He came first under the influence of American educational ideas when at the age of seventeen he entered Sapporo Agricultural College, an institution organized by William Smith Clark, President of the Massachusetts Agricultural College, under a special grant of the Japanese Government in 1875. Among the members of his class (1884) were the geographer Jugo Shiga, the journalist Gentei Zumoto and the statesman Tetsuji Hayakawa. From 1884 to 1886 he studied zoology at the University of Tokyo under Mitsukuri; from 1886 to 1890 he studied with William Keith Brooks at the Johns Hopkins University, held the Bruce Fellowship and received his Ph.D. degree there in 1890. Among his fellow students there were—E. G. Conklin, T. H. Morgan and E. A. Andrews. Then followed his years at Clark University, at Woods Hole and at the University of Chicago with C. O. Whitman, until his return to the University of Tokyo in 1899. From this institution he received the degree of D.Sc. in 1899, and succeeded Mitsukuri as head of the zoological department there in 1901.

He returned to America in 1907 as Japanese delegate to the International Zoological Congress held in Boston. On his return to Japan he took with him bullfrogs, which have become established in Japan and are very generally cultivated there as an article of food. Again on a trip to India in 1909–1910 he brought back the mongoose and established it in Japan on the Okinawa Islands, where it has almost exterminated venomous snakes which formerly caused serious loss of life. In 1922 on the occasion of another trip to the United States and Canada he inves-

tigated fox-breeding, and introduced the practice into Japan.

His interest in the domestication of wild animals was joined to an interest in their preservation in his native country, together with a life-long interest in the preservation of natural monuments in Japan. He was largely influential in the passage of laws and in the organization of a society relating to the preservation of the natural and historic monuments of Japan (1911 and 1919). Under the latter law he was put in charge of a committee on preservation of wild animal life, and worked on this subject for the remainder of his life, making a survey of some thirty-four animal species to be specially protected, including various birds, mammals, reptiles and rare marine species.

Watasé's doctoral dissertation was on "The Morphology of the Compound Eyes of Arthropods" based on a study of the structure and development of the compound eyes of Limulus with a comparison of many other representative arthropods. It was an epoch-making work in its field, and several of the artistically executed figures have long been standard illustrations of the subject. He then came under the influence of Whitman at Woods Hole and his next published work bears the marks of this influence. It deals with the cleavage of the ovum of the squid (Loligo) and was intended as the first of a series of studies on cephalopods. However, it served to introduce him to the field of cytology, and the proposed cephalopod studies were laid aside. During the remainder of his stay in America, until 1899, he devoted himself exclusively to cytological work. He had the great advantage during this time of being a member of Whitman's staff at Clark University (1890–1892), at the University of Chicago (1892–1899) and at Woods Hole. This insured him freedom for research, a situation that exactly suited his scholarly temperament. Although his activity was incessant, he did not publish much, being content to present the results of his work and thinking from time to time in the form of lectures or brief articles.

His publication on the cleavage of the egg of Loligo was a contribution of permanent significance, especially his observations on the bilaterality of the ovum and his ideas on its promorphology. The material proved excellent for the study of karyokinesis and led him into studies of the centrosome, and finally the nature of cell organization. A lecture on this subject published in the Woods Hole Biological Lectures 1893, presents the idea that the relation between the cytoplasm and nucleus of the cell is a kind of symbiosis, similar to that exhibited in the organization of a lichen. This idea, consistently and thoughtfully developed, as it is, has in it much for the fruitful consideration of modern cytologists.

In 1895 in a lecture on "The Physical Basis of Animal Phosphorescence" Watasé quotes the poet Fletcher (1637)

> You gaudy glow-worms, carrying seeming fire,
> Yet have no heat within ye!

and continues with observations from Robert Boyle (1667–1668), Faraday (1814) and others, in a way that shows his remarkable acquaintance with English literature, before proceeding with an interesting analysis of the subject in hand. This was one that satisfied both his scientific and his artistic nature, and was carried by him during the remainder of his stay in America; afterwards in Japan the subject of luminous organisms remained a favorite interest, as evidenced by his popular work in the Japanese language on this subject (1902).

In addition to the interests that he carried on in Japan already cited, he was an assiduous collector of animals and a student of ecology, which subject he studied on numerous trips to every corner of the islands of Japan; this interest led him to establish with the aid of students and friends a society for the study of the ecology of animal life of Eastern Asia.

Under a grave and serious manner Watasé was very warm hearted; he was considerate of other people and courteous in his attitude. To his students he was kindly, but never familiar; he corrected their dissertations with care and insisted on a good style of presentation.

Throughout his life Watasé was a man of many interests. During his stay in America he was one of the best read of his associates here in general literature and science; he had a lively interest in world politics, and was regarded as a special authority on Japanese art. He employed much of his leisure time in America in studying Japanese prints and paintings in various museums and libraries throughout the United States. On his return to Japan he became a member of the newly organized Institute for Japanese Arts and was a regular attendant at the monthly meetings where artists assembled to discuss and criticize Japanese paintings. He also maintained and enlarged his interest in European and American literature.

Watasé was twice married, in 1901 to Miss Yoshi, daughter of Viscount Arata Hamas, President of Tokyo Imperial University. She died in 1905, and three years later Watasé married again, the sister of one of his colleagues of the Imperial University. His home life was peaceful and happy. One of his two daughters by his first marriage and two sons by his second marriage survive him. His second wife died suddenly in August, 1928; in September of the same year Watasé himself was taken ill, but lingered on until March.

F. R. LILLIE
SHIGEO YAMANOUCHI

RECENT DEATHS

DR. JESSE WALTER FEWKES, ethnologist of the Bureau of American Ethnology from 1895 to 1917 and from 1918 until his retirement in 1928 chief of the bureau, died on May 31 in his seventy-ninth year.

DR. GEORGE NEIL STEWART, professor of experimental medicine and director of the H. K. Cushing Laboratory of Experimental Medicine at Western Reserve University, died on May 28, at the age of seventy years.

DR. GEORGE WASHINGTON PATTERSON, associate dean of the College of Engineering of the University of Michigan, died on May 22, at the age of sixty-six years.

DR. WOODS HUTCHINSON, physician and author, died on May 26, at Brookline, Massachusetts. He was sixty-eight years old.

DR. BENJAMIN A. THOMAS, professor of urology in the Graduate School of Medicine of the University of Pennsylvania, died on May 29, aged fifty-one years.

SCIENTIFIC EVENTS

THE CONVERSAZIONES OF THE ROYAL SOCIETY

THE first of the two conversaziones given annually by the Royal Society was held at Burlington House on May 14, when the guests were received by the President, Sir Ernest Rutherford.

The exhibits, as described in the London *Times*, were scarcely as numerous as usual, and a large proportion of them came from various research institutions. The National Physical Laboratory, for instance, showed an apparatus for making friction and wear tests on pivots and jewels and a hygrometer for use in ships carrying refrigerated cargoes, while among examples of work it has carried out for the Radio Research Board it arranged a demonstration of the reception and recording of signals from the Orfordness rotating wireless beacon. The Building Research Station had on view a meter for investigating the flow of heat at a window into or out of a room, and the Research Department, Woolwich, exhibited a proposed method for the visual examination, by means of X-rays, of flaws in long cylinders, such as gun tubes or gas cylinders. The astronomical exhibits included two photographs from the Radcliffe Observatory, Oxford, of the new trans-Neptunian planet, which appeared as a minute black dot, and a recording microphotometer was sent jointly by the Solar Physics Observatory, Cambridge, and the Cambridge Instrument Company.

Dr. L. J. Spencer, of the department of mineralogy of the Natural History Museum, showed experiments illustrating the luminescence of zinc-blende when scratched or struck—a property possessed by specimens from only a few localities—and Mr. G. C. Robson, of the zoological department, had a model of a remarkable ten-armed cephalopod, the only known specimens of which were obtained in 3,000 meters off the Cape Verde Islands and in the Pacific. The control of fungal wastage in citrus and other fruits, by maintaining a certain concentration of acetaldehyde vapor in the storage atmosphere, was illustrated by the Low Temperature Station, Cambridge, and the Forest Products Research Laboratory, by means of an instrument which measures the proportion of fibrous tissue in a sample of wood, showed how anatomical methods are applied to investigating the technical properties of timber.

General attention was attracted by a series of about 80 illuminated transparent photographs, taken by Dr. Pole Evans and hand-colored by Mrs. Pole Evans, representing different types of the natural scenery of South Africa. Professor E. N. da C. Andrade demonstrated the mechanism of ridge formation in sounding tubes, Mr. L. S. B. Leakey showed the Leakey-Harper drawing machine originally designed to facilitate the accurate detailed drawing of human skulls, Mr. R. S. Whipple sent a silver geographical globe engraved at Venice in the second half of the sixteenth century, and Sir Robert Hadfield, among other exhibits, had in operation an electric furnace with heating elements composed of a new heat-resisting alloy which enables temperatures as high as 1,200° C. to be maintained continuously.

Professor D. M. S. Watson gave the usual illustrated lecture, his subject being the flight of pterodactyls.

RESEARCH BUILDING OF THE MELLON INSTITUTE

DR. EDWARD R. WEIDLEIN, director of the Mellon Institute of Industrial Research, has announced, speaking for the Board of Trustees, that the institution is to increase its facilities by a building project for its research activities. Detailed plans are now being prepared by the architects, Janssen and Cocken, of Pittsburgh, and construction will begin as soon as the drawings are completed. The Mellon-Stuart Company, also of Pittsburgh, is the general contractor.

When the present home of the institute was completed, in 1915, it was felt that the industrial fellowship procedure created by Robert Kennedy Duncan had passed from the experimental to the practical

stage. The building, which was given to the institution by Andrew W. and Richard B. Mellon, incorporated the best laboratory constructional features of that period. It was thought then that it would provide adequate space for growth for many years; but for practically ten years the institute has had a waiting list of companies, often almost as long as the roster of companies whose problems were being investigated. Even the additional space afforded by Building No. 2, acquired in 1927, gave but temporary relief.

In addition to providing a greatly increased number of laboratories, the new building will give larger quarters for the general departments. The present library contains 11,000 volumes; the new library is planned to accommodate 250,000 volumes. The present department of research in pure chemistry will be expanded and facilities for pure research in other branches of science will be provided. Much more elaborate chemical engineering laboratories are to be available in the new building, and also the fellowships in each specific field of industrial research are to be grouped in suites of rooms. Certain rooms will be equipped for specialized phases of experimental technique, such as electrochemistry, spectroscopy, low-temperature studies, radiations, high-pressure experimentation, etc. Other features are a large lecture hall, a dining hall, an industrial fellowship museum and an underground garage. For the past five years members of the institute's executive staff have been visiting laboratories in America and Europe to obtain information on new features in design and equipment.

The building will be of Greek design, seven stories high, with monolithic columns along all four sides. The proportions will be approximately 300 feet by 400 feet. The main entrance, which is on the third floor, is reached by steps extending along the entire front of the building. The laboratories are to face on interior courts. The design is to be such that additional laboratory suites can be constructed in the interior courts without marring the appearance and without interfering with the original laboratory units.

SYMPOSIUM ON THE KIDNEY IN HEALTH AND DISEASE

THE University of Minnesota Medical School is issuing invitations to an interesting experiment in scientific coordination, a Symposium on the Kidney in Health and Disease, to take place at the University Hospital in Minneapolis from July 7 to 18.

Dealing with a relatively well-defined subject, but with the program occupying not less than ten working days and listing a considerable number of speakers of distinction, the symposium aims at a presentation and integration of the motley collection of material from anatomy, physiology, pathology, biochemistry, ophthalmology, internal medicine and pharmacology that make up our knowledge of Bright's disease. No attempt will be made to present the entire knowledge of the kidney in health and disease, but an effort will be made to discuss those chapters where our knowledge has recently been extended in an important way or where progress has been difficult to achieve, but investigative efforts are intense. The program is composed of papers, clinics and round table discussions. Among the different topics we pick at random the relationship between kidney structure and function, nutrition and bodily growth (G. C. Huber, C. M. Jackson, R. E. Scammon), comparative anatomy and physiology (E. K. Marshall, H. L. White), nature of glomerular function and theory of kidney secretion (A. N. Richards, P. Rehberg from Professor Krogh's laboratory, Copenhagen), chemical functions of the kidney (J. L. Gamble), functional tests (L. G. Rowntree, P. Rehberg, F. Hinman), the problem of edema (A. D. Hirschfelder, L. Leiter, B. Hastings, P. Rehberg), the pathological anatomy of Bright's disease (E. T. Bell), its clinical manifestations (F. Volhard of Frankfort on Main, I. Snapper of Amsterdam, W. T. Longcope), the retinal changes in nephritis (H. P. Wagener), uremia (F. Volhard, Butler of K. D. Blackfan's Clinic), diuretics and treatment (R. N. Bieter, L. G. Rowntree, N. M. Keith, F. Volhard).

The final program will be issued shortly. Information in regard to the symposium may be obtained from Dr. Hilding Berglund, University Hospital, Minneapolis, Minnesota. Accommodations for visitors are being provided through the university.

THE PACIFIC DIVISION OF THE AMERICAN ASSOCIATION

THE annual meeting of the Pacific Division of the American Association for the Advancement of Science will be held at the University of Oregon from June 18 to 21.

The "Origin of Land Plants" is the subject of the annual president's address by Dr. Douglas H. Campbell, of Stanford University, which will be given on Wednesday morning.

A review of the progress of research on the Pacific coast and in the far west will open the session Wednesday afternoon, June 18. Dr. Richard B. Dillehunt, dean of the University of Oregon medical school in Portland, and Dr. C. B. Lipman, University of California, will survey the field of the life sciences. Dr. J. A. Anderson, of the Mount Wilson Observa-

tory, and Dr. R. B. Brode, of the University of California, will describe the principal accomplishments in the physical sciences. The sound film of Sir William Bragg, "Arrangement of Atoms and Molecules in Crystals," and the film by C. W. Hewlett on "Radioactive Rays," have been secured for this opening session.

A feature of the meeting will be a symposium on trees, on Thursday morning. Among those taking part are Dr. Wilson Compton, secretary-manager of the National Lumber Manufacturers' Association, Washington, D. C.; Dr. Thornton T. Munger, Portland, director of the Pacific Northwest Forest Experiment Station, and Dr. A. E. Douglass, director of the Steward Observatory, University of Arizona. Dr. W. F. G. Swann, director of the Bartol Research Foundation of the Franklin Institute, Swarthmore, Pennsylvania, will address the meeting on Friday evening on "Philosophic Concepts of Modern Physics."

Friday afternoon will be devoted to a tour of inspection of the Oregon State Agricultural College at Corvallis. Several excursions have been planned to places of scientific and scenic interest. These include a trip to Coos Bay, where the university is contemplating the establishment of a biological laboratory; a trip over the McKenzie Highway to the summit of the Cascade Range, to view geological features; a geographical trip to the coast to Newport and Yaquima Bay; a third trip will take in the various lumber mills and logging camps near Eugene; a paleobotany trip will be made to the fossil beds about eight miles south of Eugene; a tour of inspection to the Springfield Booth-Kelly lumber mill will be made; the new municipal power plant and dam recently completed at Leaburg will be the subject of the seventh trip. President and Mrs. Arnold Bennett Hall, of the University of Oregon, will hold a reception on Wednesday afternoon.

Members resident in Montana and Wyoming desirous of attending this meeting may benefit from the reduced transportation rates secured under the identification-certificate plan. These certificates may be secured from the secretary of the Pacific Division, American Association for the Advancement of Science, Stanford University, California. Requests should be made immediately. Identification-certificates to members resident in California, Oregon, Washington, Nevada, Utah, Idaho and British Columbia will be sent out with the programs. Identification-certificates to non-members of the association who propose to attend the meeting will be issued on request.

SCIENTIFIC NOTES AND NEWS

A special feature of the meeting of the American Medical Association to be held at Detroit this month will be the presentation to all the living ex-presidents of the American Medical Association of an emblem significant of medical science. The four senior presidents are Dr. W. W. Keen, Philadelphia, president in 1900; Dr. Frank Billings, Chicago, 1902; Dr. W. J. Mayo, Rochester, Minnesota, 1906, and Dr. W. H. Welch, Baltimore, 1910.

A portrait bust of Professor James Henry Breasted, director of the Oriental Institute of the University of Chicago, will be cast in bronze by the French sculptor, Numa Patlagean, in Paris, and will be installed in the new building of the Oriental Institute.

The engineering faculty of New York University gave a dinner on May 28 in honor of Dean Charles H. Snow, who is retiring after thirty-eight years with New York University, thirty-three of them as head of the Engineering College.

At the third organization dinner of the Brooklyn Botanic Garden an illuminated and framed parchment scroll was presented to the director, signed by the staff and employees of the garden, fifty-four in number. The scroll reads: "Presented to Dr. C. Stuart Gager on May twenty-second, nineteen hundred and thirty, to mark the twentieth year of his association with the Brooklyn Botanic Garden as its director. This scroll is an expression of admiration for the work that he has accomplished and of the respect and affection with which he is regarded by the entire personnel of the Brooklyn Botanic Garden."

Dr. Francis E. Lloyd, Macdonald professor of botany at McGill University, has been elected a corresponding member of the Czechoslovak Botanical Society.

The Royal Geographical Society has awarded its Cuthbert-Peet Grant for 1929 to Mr. Owen Lattimore for his travels in Mongolia and Sinkiang recorded in his recently published book "The Desert Road to Turkestan."

A portrait of Professor H. F. Newall, who recently retired from the chair of astrophysics at the University of Cambridge, was presented to the university on May 10. The portrait was painted by Mr. Fiddes Watt and the presentation was made by Sir J. J. Thomson. Sir Frank Dyson and Sir Joseph Larmor spoke in appreciation of Dr. Newall's work.

It is stated in *Nature* that the Royal Society of Edinburgh has made the following awards: Keith Prize for the period 1927–29, to Dr. Christina C. Miller, for her papers on the slow oxidation of phosphorus trioxide, published in the *Proceedings* within the period of the award, and in consideration of subsequent developments on slow oxidation of phosphorus, published elsewhere; the Neill Prize for the period 1927–29, to Professor E. B. Bailey, in recognition of his contributions to the geology of Scotland, two of which have recently appeared in the *Transactions* of the society; the James Scott Prize for the period 1927–30, to Professor Niels Bohr, who delivered an address, according to the terms of the award, on May 26.

At the anniversary meeting of the Royal Society of South Africa, Dr. W. A. Jolly, dean of the medical faculty at the University of Cape Town, was elected president.

At the seventh annual meeting of the American Society of Stomatology held in New York on April 10 and 11, elections were made as follows: Dr. Lloyd L. Baker, Eugene, Oregon, *president;* Dr. N. P. Norman, New York, *vice-president;* Dr. Alfred J. Asgis, New York, *editor-secretary;* Vida A. Latham, Chicago, and Dr. A. T. Rasmussen, La Crosse, Wisconsin, *fellows;* Professor Oliver T. Osborne, Yale University; Professor J. Chompret, director, stomatology division, St. Louis Hospital, Paris; Professor A. Herpin, Paris; Professor G. Coen-Cagli, University of Rome; Professor Antoni Cieszynski, University of Lwow, *honorary fellows.*

Officers elected at the annual meeting in Atlantic City of the American Laryngological, Rhinological and Otological Society were: Dr. Max Goldstein, St. Louis, *president;* Dr. Coulter G. Charlton, Atlantic City, *vice-president;* Dr. W. Likely Simpson, Memphis, Tennessee, *chairman of the Southern Section;* Dr. Albert C. Furstenburg, Ann Arbor, Michigan, *chairman of the Middle Section;* Dr. Claudet Uren, Omaha, Nebraska, *chairman of the Mid-Western Section;* Dr. A. T. Wanamaker, Seattle, Washington, *chairman of the Western Section;* Dr. Robert L. Loughran, New York, *secretary;* Dr. Ewing W. Day, Pittsburgh, *treasurer,* and Dr. George I. Richards, Fall River, Massachusetts, *editor.*

Dr. Louis Kahlenberg, professor of chemistry at the University of Wisconsin, was elected president of the American Electrochemical Society at the recent meeting in St. Louis. Other officers elected were Bradley Stoughton, Hugh S. Taylor and George W. Vinal, *vice-presidents;* D. A. Pritchard, M. R. Thompson and Alexander Lowy, *managers;* Acheson Smith, *treasurer,* and Colin G. Fink, *secretary.*

Dr. Homer H. Lowry, research chemist with the Bell Telephone Laboratories, Inc., New York City, has been selected as director of the recently founded Coal Research Laboratory of the Carnegie Institute of Technology.

Dr. William F. Thompson, director of the International Fisheries Commission, with scientific headquarters at the University of Washington, has accepted the newly created post of research professor of fisheries. His new work will not conflict with his duties on the commission, which is jointly supported by the United States and Canada for the study of the halibut fisheries, particularly in the North Pacific. Under the new plan, which will go into effect next October, the oceanographic work at the university will coordinate studies in the biology of the sea, including plant and animal life, the chemistry of the ocean waters and the geological structure of submarine areas and ocean currents. The present College of Fisheries will be consolidated with the College of Sciences to give students a more thorough scientific foundation for the study of marine animal life.

Dr. H. E. White, international research fellow at the Physikalisch-Technische Reichsanstalt, Charlottenburg, has accepted a position as assistant professor of physics at the University of California. Dr. White will begin his duties at California with the opening of the fall semester in August.

Professor Max F. Meyer, of the University of Missouri, has been appointed research professor of psychology for one year, and has been relieved from all his teaching and administrative duties. His work will be concerned with methods of teaching the deaf and will be carried on with the clinical facilities of the Central Institute for the Deaf in St. Louis.

Dr. J. E. W. Wallin, director of special education in the Baltimore public schools and lecturer at the Johns Hopkins University and Morgan College, has been appointed head of the department of psychology at Atlantic University which was recently founded at Virginia Beach.

Dr. Herbert C. Hanson, of the Colorado Agricultural College, has been appointed professor of botany and head of the department of botany in the School of Science and Literature and botanist in the Experiment Station in the North Dakota Agricultural College at Fargo. He will take up his new duties on July 1.

Dr. Clarence A. Morrell, formerly of the department of biochemistry of the Harvard Medical School, has taken the position of chemist-pharmacologist in the laboratory of hygiene of the Department of National Health at Ottawa, Canada.

DR. HENRY S. SHARP, instructor in geology at Columbia University, has been appointed assistant professor of geology in Denison University, Granville, Ohio.

DR. JULIA M. SHIPMAN, instructor of geography at the University of Nebraska, has been appointed assistant professor of geography at Mount Holyoke College.

THE following appointments are announced at the Iowa State College: Francis Ellis Johnson, head of the department of electrical engineering at the University of Kansas, head of the department of electrical engineering; G. W. Fox, of the University of Michigan, assistant professor of physics; H. V. Gaskill, of the Ohio State University, assistant professor of psychology; James F. Yeager, of New York University, assistant professor of physiology.

AT the University of Michigan Professor E. B. Mains, of Purdue University, has been appointed professor of botany and acting director of the herbarium, effective in September. He will offer advanced work in mycology and in plant breeding for disease resistance. Professor Wm. Randolph Taylor, of the University of Pennsylvania, has been appointed professor of botany and curator of algae in the herbarium. He will remove to Ann Arbor in September. He will continue, as in the past, to conduct the summer course in algae at the Woods Hole Biological Laboratory.

AT the College of the City of Detroit, Mr. and Mrs. William Borgman, Jr., instructors in the department of mathematics, have been given leave of absence for 1930–31. They expect to spend the year in graduate study in Munich, Germany. New appointments to instructorships in this department are those of Mr. William L. Duren, Jr., formerly of Tulane University, and Mr. H. H. Pixley, formerly of Bryn Mawr College.

DR. NELS A. BENGTSON, chairman of the department of geography, the University of Nebraska, will give the work in economic geography in the summer session of Columbia University. E. E. Lackey, associate professor of geography, will give courses in geography in the summer session of Western Reserve University at Cleveland.

THE Kaiser Wilhelm Institute for Medicine at Heidelberg was opened on May 25. It has departments of pathology, physiology, physics and chemistry under the direction of Dr. L. von Krehl, Dr. Otto Meyerhoff, Dr. Hauffer and Dr. Kuhn, respectively.

DR. BRUCE MAGILL HARRISON, professor of biology at the University of Southern California, will spend the summer in the interior of Borneo on a scientific expedition sponsored jointly by the University of Southern California and the Universal Pictures Corporation. Dr. Harrison will leave Los Angeles about June 5.

DR. HERBERT S. REICHLE, of the department of pediatrics of the School of Medicine of Western Reserve University, has leave of absence for six months and has gone to Leipzig, where he will study under Professor Bessau. Dr. G. Richard Russell and Dr. L. P. Harsh, of the same department, are starting on August 1 for a year of European study. Dr. Russell will spend most of the time with Professor Ernst Freudenberg at the University of Marburg. Dr. Harsh will do most of his work with Professor Birk at the University of Tübingen. The department of pediatrics of the School of Medicine of Western Reserve will have two guests, beginning on September 15, Dr. Otto Beck, of the University of Tübingen, and Dr. H. Brühl, of the University of Marburg.

DR. G. H. HART, head of the divisions of animal husbandry and poultry husbandry of the University of California, expects to take a six months' trip in Europe. He will leave New York on June 13 with the official tour of the American Veterinary Medical Association through European countries for the purpose of studying research methods and equipment, attending the eleventh International Veterinary Medical Congress in London from August 4 to 9.

DR. WILLIAM ANDERSON, of the University of Aberdeen, Scotland, recently spent a week in lecturing before clinics of the School of Medicine of Western Reserve University as the guest of Dr. Elliott C. Cutler, head of the department of surgery. Before sailing Dr. Anderson planned to spend a week at the Peter Bent Brigham Hospital in Boston with Dr. Harvey Cushing.

A JOINT open meeting of the Eta chapter of the Sigma Delta Epsilon fraternity and the Kappa Mu Sigma was held on May 23 at the department of pathology of the University of Chicago. The speaker, Mrs. Dorothea Waley Singer, gave an address entitled "Folk Medicine." Dr. Charles Singer is giving lectures on the history of medicine at various universities in the United States.

THE one hundred and eighty-sixth meeting of the Medical Research Club of the University of Illinois College of Medicine was held in Chicago on May 16. This was the annual business meeting and the guest of honor was Dr. Walter H. Eddy, professor of physiological chemistry, Teachers College, Columbia University, who spoke on the "Present Status of Vitamin B." Dr. Eddy was elected to honorary membership in the club. At the business meeting which followed, Dr. Walter J. R. Camp, assistant

professor of pharmacology, was elected president for the coming year.

PROFESSOR G. W. STEWART, of the State University of Iowa, recently gave a series of four general lectures on "Modern Acoustics" to the graduate students in communication engineering, Yale University.

DURING the session of 1929–1930, the Mayo Foundation Chapter of Sigma Xi held seven regular meetings, the speakers and subjects being as follows: Dr. D. W. Morehouse, astronomer, Drake University, "What is Outside of Space"; Dr. George H. Parker, Harvard University, "Secretory Activity of the Nervous System"; Dr. Major G. Seelig, Washington University, St. Louis, "Animal Behavior in the Development of Medicine and Surgery"; Mr. Vilhjalmur Stefansson, "Experiences in the Arctic Region"; Dr. Harry Miles Johnson, psychologist and senior fellow, Mellon Institute, "Experimental Studies on Sleep"; Dr. Robert G. Green, associate professor of bacteriology, University of Minnesota, "Epizootic Encephalitis of Carnivorous Animals"; Dr. H. E. Robertson, Mayo Clinic, "The Colorado River."

APPLICATIONS for park naturalists of various grades must be on file with the Civil Service Commission at Washington, D. C., not later than June 25, 1930. The examinations are to fill vacancies in the National Park Service of the Interior Department, for duty in the field and in positions requiring similar qualifications. The entrance salaries are $3,800 a year for park naturalist, $3,200 a year for associate park naturalist, $2,600 a year for assistant park naturalist. Higher-salaried positions are filled through promotion. Competitors will not be required to report for examination at any place, but will be rated on their education and experience, and on a thesis or publications.

BY the will of the late Fridtjof Nansen, $25,000 is bequeathed to the Nansen fund of the Norwegian Society of Science.

YALE UNIVERSITY has been made the residuary legatee of the estate of Miss Mary E. Hawley, of Newtown, Connecticut, from which it is estimated that it will receive $2,000,000. There are no limiting conditions except that the income from the fund shall be applied to the "general uses and purposes of the university."

THE Massachusetts Institute of Technology is the remainder legatee of the residue of the fortune of Harry B. Hunt, whose estate was appraised at $510,-979 net. Mr. Hunt, who died on July 25, 1929, was for many years connected with the American Locomotive Company.

BY the will of Dr. William J. Matheson, formerly president of The National Aniline and Chemical Company, $600,000 is bequeathed for medical research. In 1927 Dr. Matheson provided funds for an international survey of sleeping sickness. In his will, dated October 10, 1929, he bequeaths 4,200 shares of stock of the Corn Products Refining Company (with a present market value in excess of $400,000) to the William J. Matheson Foundation, a corporation for charitable and educational purposes which the testator intended to organize. The management of the foundation is authorized to apply the income to the encouragement and support of medical research and for any other charitable or educational purpose. Among the foundation's first activities, the will states, should be to take over or contribute to the expenses of the survey of epidemic encephalitis and similar research work now carried on by a committee of which Dr. William Darrach is chairman. The principal of a $200,000 trust fund is to be paid later to the Matheson Foundation.

To provide for a complete museum of the graphic arts in the Benjamin Franklin Memorial to be erected on the Philadelphia Parkway, Mr. A. Atwater Kent has contributed $220,000 toward the $5,000,000 fund being raised for the memorial. The section is designed to show how modern methods of recording and transmitting information have developed from the crudest efforts of mankind. It will be housed in a section of the building at the front and immediately adjacent to the memorial chamber, extending from the ground floor to the roof, and consisting of a lower floor and an upper floor with two galleries. The ground floor will contain printing presses and other heavy machinery used in the graphic arts. Above will be an exhibition starting with the earliest recorded writing of man, crude sketches on the walls of caves, the various forms of writing to be illustrated up to the invention of printing by Gutenberg, and then to present-day means and methods. Among the original exhibits will be Franklin's own composing table, original press, now owned by the Franklin Printing Company, and some of his books and the manuscripts that he printed.

THE purchase of 422,737 acres of forest land at a cost of $1,202,172 has been approved by the National Forest Reservation Commission. The commission has also approved the establishment of new federal purchase units in Kentucky, Arkansas, Mississippi and Louisiana. The purchase program provides for the acquisition of a total of 539 tracts of land at an average cost of $2.84 per acre in Alabama, Pennsylvania, North and South Carolina, Tennessee, Louisiana, Georgia, Florida, Wisconsin, Michigan, West

Virginia, Virginia, Arkansas, Minnesota and New Hampshire.

PRELIMINARY examinations of eight rivers in various parts of the United States with a view to the control of their floods would be authorized under the provisions of a bill reported from the House Committee on Flood Control. The preliminary examinations, according to the accompanying report, would be made for the purpose of ascertaining what a detailed survey would cost; what federal interest, if any, is involved, and what share of the expenses, if any, should be borne by the United States. The following streams and rivers would be included in those on which the examinations would be made: The Titabawassee and Chippewa rivers in Michigan, the Mohican River in Ohio, the Hocking River in Ohio, the Mokelumne River and its tributaries in California, the Waccamaw River in North and South Carolina, the French Broad River in North Carolina, the Fox River in Wisconsin and the Cumberland River and Yellow Creek in Kentucky.

DISCUSSION

HOW OLD IS THE PLEISTOCENE?

THE exploration of the cavern known as Gypsum Cave near Las Vegas, Nevada, is yielding important information concerning those hazy and nebulous years that separate the Pleistocene and Recent periods, in other words, the domains of paleontology and archeology.

The Southwest Museum of Los Angeles and the California Institute of Technology are cooperating in this work, which is in charge of Curator M. R. Harrington, of the former institution, with Dr. Chester Stock and Dr. E. L. Furlong, of the latter, in frequent consultation.

On the paleontological side the most interesting finds thus far have been in connection with the extinct ground-sloth Nothrotherium, which is one of the typical animals of the Pleistocene. Not only the bones but also large claws with horny covering still intact have been recovered, as well as its long, coarse, tawny hair and even bits of skin all preserved by the dryness of the cave. Very unusual also are the large beds of sloth dung in which the remains of the animal are usually found imbedded. Among other Pleistocene species represented in the cave are indigenous horses and an American camel.

On the archeological side, although some remains have been found left by Early Pueblo visitors probably from the settlements in the Moapa Valley thirty or forty miles eastward and even by the more recent Paiute, most of the artifacts thus far recovered from the cave may be attributed to the Basket-makers. These are the earliest people hitherto known to have occupied the Southwest and are supposed to have flourished about 1500 B. C.

It now appears that even earlier people had visited the cave, for pieces of painted wooden dart shafts unlike Basket-maker products have appeared at considerably greater depths than the deposits yielding typical Basket-maker artifacts.

Most important of all is the gradually accumulating evidence suggesting that the earliest human visitors and the last of the sloths may have occupied the cave at the same time. None of the evidences in themselves can be called conclusive, but taken together they merit serious consideration.

For example, we have in one archeological deposit a deeply buried stratum containing large pieces of sloth dung, charcoal and scattered artifacts. In another instance we have specimens of the painted broken darts mentioned before recovered at depths below the surface of from eight to ten feet, beneath a stratum of sticks containing sloth dung and hair, and in still another instance quartzite dart points of archaic form buried in the bottom of a rockslide near the surface of which, beneath a large slab, was found a nearly perfect sloth skull.

Farther back in the cave the compact layers of sloth dung have yielded a few pieces of dart-shafts and of burnt sticks once apparently used as torches; and in the crevices of the rocks, sloth dung, bones of the sloth and artifacts have frequently been found in association, but in the last case the evidence is of less value than in the previous instances.

Should the association of man and sloth be finally established beyond doubt an interesting question arises. Shall we postulate that man existed in America twenty or thirty thousand years ago, which is the age generally attributed to the last phases of the Pleistocene, or shall we assume that Pleistocene animals and possibly conditions persisted until within ten or fifteen thousand years or possibly even less? In other words, just when did the Pleistocene end?

M. R. HARRINGTON

Since the foregoing article was written, Mr. Harrington has discovered in Gypsum Cave evidence which to his mind "establishes the association of man and the sloth beyond question." The Southwest Museum, which owns Gypsum Cave, will endeavor to preserve the evidence *in situ*, without disturbance, so

that any well-accredited scientists who feel so disposed may investigate it at their leisure.

JAMES A. B. SCHERER

THE SOUTHWEST MUSEUM,
LOS ANGELES, CALIFORNIA

THE FUTURE OF TAXONOMY

THERE is one point in Dr. Mickel's interesting discussion[1] which seems to need further comment. He refers to the small group of taxonomic workers in Washington, "flooded with specimens of insects sent in from all parts of the country for identification, so that the amount of time that can be spent in actual research is exceedingly small." Also to the specialist on Coccidae "so loaded down with routine identification work and administrative duties that he has practically no time for research." Whatever may be said concerning the ability or industry of particular workers, we are here concerned with a matter of policy, and criticism must be directed to those "higher up"—ultimately to the highest power, the people of the United States, who permit such things to be. The truth is, however, that in the long run, even with existing facilities, it would pay to do much more revisional or monographic work. Only a few days ago I received a letter from a worker in the National Museum, explaining the difficulty of conducting exchanges, because so many of the species of a certain group were erroneously identified. Without revisional work, the museum collection may well be a source of error. Specimens come in from many workers, and it is impossible to check up the identifications as they are put away. Even specimens labeled "type" can not always be trusted, as has been shown by a National Museum specialist in a paper just published. Then again, in the absence of adequate monographs, entomologists give up the idea of determining their species, and at the same time the idea of studying them. Consequently, even when they receive names for their specimens, they often do not know the species, and will not recognize them again. The practice of wholesale determination of specimens has faults analogous to those of indiscriminate charity.

On the other hand, if, with enlarged resources, we went to work cooperatively to monograph our fauna, we could enable serious students to work up their own materials. They would, of course, find difficulties, and would be entitled to assistance from the museum or bureau, after they had tried to help themselves. This assistance would be cheerfully given, with the knowledge that it would promote study, instead of preventing it. Identifications, based on revisional work and not on the labeling of specimens, derived from various sources, in the collection, would be far easier and more accurate. Time would be saved for all concerned, except those who have been in the habit of requiring a specialist to do their work for them. Broadly, then, we need more constructive imagination.

T. D. A. COCKERELL

UNIVERSITY OF COLORADO

[1] Clarence E. Mickel, "The Future of Taxonomy," SCIENCE, 71: 436, April 25, 1930.

INACTIVITY OF CHICORY[1]

RESULTS previously reported[2] indicated absence of stimulative effect of infusions of chicory on isolated intestinal segments. Later repeated observations of no gastro-intestinal response in intact rabbits, dogs and guinea-pigs to massive doses of such infusions seem to indicate further that chicory, in the form used as a beverage ingredient, probably has no laxative effect.

Such a quantity of the root is popularly consumed that it was thought worth while to investigate other possible actions. A careful series of urine secretion determinations in man (myself) and guinea-pigs have yielded, without exception, quantitatively negative results. Intravenous or stomach tube administration of as much as 60 cc of a 20 per cent. infusion produced no observable effect or discomfort in intact guinea-pigs. Substitution of an alcoholic extract (evaporated to alcohol-free) for the infusion made no difference in the complete negativity of the findings.

The only indication of a possible drug action encountered was a tetanus-like hyperexcitability of frogs which had received the relatively tremendous dose of 2 cc of a 20 per cent. evaporated tincture (roughly equivalent to 5,600 cups of an average coffee-chicory blend in man). Administration of virtually unlimited dosage failed to elicit any comparable effect in mammals. It seems quite probable that chicory has no particular pharmacological significance as used in coffee mixtures.

CHAPMAN REYNOLDS

MARQUETTE UNIVERSITY
SCHOOL OF MEDICINE

CAN A CATFISH COUNT?

A BULLHEAD catfish (*Ameiurus nebulosus*) which had been maintained since babyhood in a twenty-three-gallon all-glass tank of still water with several others of its kind was between three and four years old when it evolved a method of entertaining itself that may be called unique considering the general absence of a spirit of play in this group of fishes.

A single spray of Canadian water-weed (*Anacharis*) trailed about a foot from the main plant, touching the glass at the rear of the tank (*i.e.*, the side

[1] From the Departments of Physiology and Pharmacology, Marquette University School of Medicine, Milwaukee.

[2] C. Reynolds, *Proc. Soc. Exp. Biol. and Med.*, 25: 696, 1928.

away from the light). The catfish, which was called "White Whiskers" because the four "chin" barbels were white, was seen every day circling this spray. It always moved over the spray, then under, always proceeded from the left to the right of the tank, and showed a preference for making the swing an even number of times before coming to rest.

Often it was observed at play when there was not time to count its motions, but on five different days its circuits in this peculiar game of solitaire were counted. On one day it played fifteen games, during which it recorded in all 115 swings around the spray. On the five days it played forty games and traced the circle 263 times!

In these forty games the fish came to rest thirteen times after completing the circle an odd number of times (from one to nineteen), but on twenty-seven occasions it recorded an even number of swings(two to sixteen).

Was it merely a matter of chance. or did the catfish derive some conscious physical satisfaction from encircling the spray an even number of times?

IDA MELLEN

NEW YORK AQUARIUM

SCIENTIFIC APPARATUS AND LABORATORY METHODS

RECORDING CEREBRAL ACTION CURRENTS

ACTION currents from the cerebral cortex of the dog have been obtained by using five stages of vacuum tube amplification recording with an oscillograph. The operation which exposed the surface of the cortex was performed under both general and local anesthesias. Records were taken after recovery of the dog from the general anesthesia. Precautions were developed which have insured the minimal operative shock. Records were made with a film speed of twenty-one inches per second.

We have succeeded in recording from at least three distinct parts of the cortex, namely, portions of the occipital lobe, areas on the boundary of the temporal and parietal lobes and from the motor areas in the frontal lobe. These action currents appear to be of the same general nature as those obtained from the peripheral nerves. There would appear to be no very essential difference between different parts of the cortex in the form or frequency of the impulses themselves. At any one point one may obtain a wide variety of temporal and intensity relationships between the impulses.

From the degree of simplicity of patterns obtained with relatively large electrodes, it is inferred that a high degree of localization of function is not the case. Our largest electrodes covered about one four-hundredth of the brain surface. It may be readily seen that this is not at all sufficient to give spatial reference to nearly all the discriminable functions that the psychologist knows. We must fall back upon temporal factors within these areas, qualitative factors there, or functional patterns involving perhaps large portions of the cortex.

In general, we get records from the so-called motor and somesthetic areas with active movements of the dog, from the somesthetic and not from the motor in passive movements and slight effects in the visual area with a change from light to dark in the room. In certain cases we obtained records from the so-called visual area during active movement of the dog. This may indicate that this so-called sensory area was in this case an integral part of the dynamic pattern which gave rise to the movement. It would appear, however, that there must be a spatial factor in this dynamic pattern in order to give a sufficiently differentiated reaction here to correspond with our experimental data. The limited complexity of the records which we obtained makes it impossible to account for all the differences in the reactions of the animal in terms simply of the type of patterns on the records. Specialization of function, that is, the existence of a spatial element in the functioning of the cortex, is a fact, but we do not know as yet the degree to which this specialization is true or its constancy over a period of time.

Further work is in progress along all the lines suggested.

S. H. BARTLEY
E. B. NEWMAN

UNIVERSITY OF KANSAS

A CONVENIENT AID IN BALANCING CENTRIFUGE TUBES

A 15-CM dental chip blower syringe of about 50 cc capacity with right-angled delivery tube has been found to be very convenient in balancing centrifuge tubes. With this syringe the rate of delivery of water is much more easily controlled than with the commonly used large dropping pipette, and it has the distinct advantage of being unbreakable. It is convenient to place it in a wide-mouthed bottle, the bulb serving to keep the water clean. The syringe is stocked by dental supply houses and retails for about seventy cents.

H. W. ESTILL

DEPARTMENT OF BACTERIOLOGY,
UNIVERSITY OF CALIFORNIA
MEDICAL SCHOOL

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE REGULAR SPRING MEETING OF THE EXECUTIVE COMMITTEE

THE executive committee of the American Association held its regular spring meeting at the Cosmos Club in Washington on Sunday, April 27, with the following members present: Cattell, Compton, Curtiss, Hildebrand, Kellogg, Lillie, Livingston, Millikan, Morgan, Wilson. There were two sessions, one in the forenoon and the other in the afternoon. The following items of business were transacted.

1. The minutes of the last meeting of the committee were reported as having been approved by mail.

2. The permanent secretary presented a report on association affairs. The new fellowship-nomination plan, adopted at the Des Moines meeting, has been put into operation. While it may need some slight modifications, it appears to work very satisfactorily, and from now on there should be very few members eligible to fellowship who do not receive nomination. In this connection fellows are reminded that any member may be nominated for fellowship by any three fellows. Blanks for such special nominations may be had from the Washington office.

About 7,000 invitations have been sent out since the Des Moines meeting, inviting non-members to become enrolled in the association. It is planned to send out about 15,000 invitations this spring, especially to engineers, and about 50,000 invitations are to be sent out next October.

A new booklet on the organization and work of the association has been prepared, also a brief circular. These may be had on request directed to the Washington office. The new booklet contains lists of members of the several section committees.

Preparations for the Cleveland meeting next winter are well advanced. The Hotel Statler has been named general-headquarters hotel for the meeting. The Cleveland Convention Bureau and the educational institutions of Cleveland are actively engaged on the preliminary arrangements. The American Statistical Association, the American Sociological Society, the American Economic Association and the American Political Science Association all report that they will meet at Cleveland in convocation week. Most of the organizations that usually meet with the association will be meeting with it at Cleveland.

3. The Texas Academy of Science was elected to be an affiliated academy.

4. To fill a vacancy in the section committee of Section D (Astronomy), caused by the recent death of Dr. Ralph H. Curtiss, the executive committee elected Dr. H. T. Stetson, of Perkins Observatory, Delaware, Ohio, to be a member of that section committee, his term of office to expire at the end of the calendar year 1930.

5. The executive committee accepted a report that "Symbols for Heat and Thermodynamics" and "Graphical Symbols for Use in Radio Communication" had been approved for the association by its special committee acting in cooperation with the American Standards Committee. Dr. A. E. Kennelly is chairman of the special committee of the association.

6. The sum of $500 was appropriated, from the available funds of the treasury, for the cooperative project of the committee on the place of science in education (Dr. Otis W. Caldwell, *chairman*). This appropriation is to be added to the funds already raised by the committee on the place of science, to be disbursed by the permanent secretary on order of Dr. Caldwell.

7. On recommendation of the executive committee of the Pacific Division, the description of the territory of that division was modified to read as follows: "The Pacific Division (organized in 1915) includes members resident in Alaska, British Columbia, Washington, Oregon, California, Idaho, Nevada, Utah and the Hawaiian Islands." This constitutes an amendment to Article VI, Section 2, of the By-Laws and Rules of Procedure. Mexico, the Philippine Islands and other islands of the Pacific were included in the territory of the division and these regions are now removed.

8. It was voted that Dr. Carl Alsberg be asked to serve on the executive committee in the place of Dr. Joel H. Hildebrand during the latter's absence from the country.

9. A special committee was appointed to consider the relations between the natural sciences and the social and economic sciences in the Pacific region. This committee consists of Carl Alsberg (*chairman*), Arnold B. Hall, A. O. Leuschner, Charles B. Lipman and E. G. Martin.

10. The rules for the award of the American Association prize of $1,000 were modified by the following amendment: The award is to be first announced in connection with the meeting following the one at which the paper appeared on the program and the subject of the paper is to be specially presented in a public lecture at that meeting.

11. The rules for the award of the American Association prize were amended as follows: Papers by invited speakers and presidential and vice-presidential addresses are not eligible for the prize.

12. It was voted that the summer meeting of the association for 1931 shall be held at Pasadena, probably in the third week of June, the hosts for the meeting being the California Institute of Technology, the Mount Wilson Observatory and the Huntington Library.

13. It was voted that the winter meeting of 1931–32 shall be held at New Orleans from Monday, December 28, 1931, to Saturday, January 2, 1932.

14. It was voted that the association looks with favor upon New Haven as the place of the summer meeting of 1932 and upon San Francisco as the place of the summer meeting of 1934.

15. The general plan for radio talks to be given from time to time under the auspices of the Association Press Service was approved, as presented by the director of the Press Service.

16. In response to a suggestion from the director of the Press Service, Austin H. Clark, a special committee was named to consider the relations of the approaching New Orleans meeting to Latin America and to present plans for that aspect of the meeting. This special committee consists of Austin H. Clark (*chairman*), A. V. Kidder and Burton E. Livingston. It was empowered to add to its membership if additions seem desirable and was asked to present a report to the executive committee at its fall meeting, next October.

17. President Thomas H. Morgan was appointed to be the official representative of the American Association at the approaching semi-centennial of the University of Southern California, June 4 to 6, 1930.

18. Dr. Vernon Kellogg was appointed to be the official representative of the American Association at the tenth session of the Centenary of the Independence of Belgium, to be held at Brussels from June 28 to July 2, 1930.

19. A special committee, consisting of Austin H. Clark (*chairman*), Dayton C. Miller and Burton E. Livingston, was named to arrange for general and popular lectures for the approaching Cleveland meeting.

20. The appointment of Dr. H. W. Mountcastle as executive secretary of the Cleveland local committees was approved by the executive committee.

21. The permanent secretary asked that he be released from that office at as early a date as might be practicable, stating that he desired to devote more time and attention to his own field of plant physiology than would be possible in connection with his association duties, and a special committee, consisting of J. McK. Cattell, Edwin B. Wilson and Burton E. Livingston, was appointed to study the general administration of the association with respect to the retirement of the present permanent secretary and to report to the executive committee at its next meeting.

22. It was voted that the next meeting of the executive committee would occur at Washington on October 19, 1930.

BURTON E. LIVINGSTON,
Permanent Secretary

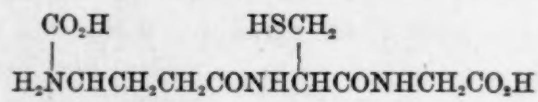
SPECIAL ARTICLES

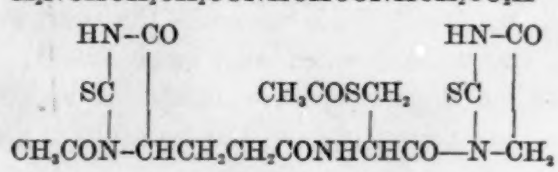
THE STRUCTURE OF GLUTATHIONE

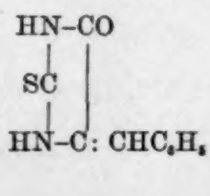
RECENTLY, clear evidence has come from two independent sources[1,2] that glutathione is a tripeptide derived from glutamic acid, cysteine and glycine. Twelve such dipeptides are possible. Six of these are eliminated by the fact[3,2] that the free amino group is that of glutamic acid.

The fact that Hopkins[1] obtained glycylcysteine anhydride by boiling glutathione with water is extremely strong evidence that glycine and cysteine are directly linked, and this consideration eliminates the two structures[4] in which both carboxyl groups of glutamic acid are involved. A study of the products obtained on oxidation with hydrogen peroxide[3,2] strongly suggests that it is the γ-carboxyl of glutamic acid which is concerned in peptide formation. Thus glutathione is a peptide of unique type and must apparently be either (A) γ-glutamylglycylcysteine or (B) γ-glutamylcysteylglycine.

The proof that the substance is correctly represented by formula B has now been obtained by its condensation with ammonium thiocyanate in acetic anhydride, which yields a product (C), nearly insoluble in water, containing two thiohydantoin rings.

B


C


D


[1] F. G. Hopkins, *J. Biol. Chem.*, 84: 269–320, 1929.

[2] Kendall, McKenzie and Mason, *J. Biol. Chem.*, 84: 657–74, 1929.

[3] Quastel, Stewart and Tunnicliffe, *Biochem. J.*, 17: 586–92, 1923.

[4] Kendall's tentative choice (footnote 2) of one of these structures was made before this evidence was published.

Condensation of this thiohydantoin derivative with benzaldehyde and subsequent treatment with alkali yields benzal thiohydantoin (D), and the formation of this product demonstrates[5] the presence in the original peptide of a glycine group with free carboxyl. Other considerations, not yet ripe for discussion here, suggest that a free carboxyl group belonging to cysteine is not also present. The formation of two thiohydantoin rings in the first condensation product (C) would also confirm the existence of a free α-carboxyl group in the glutamic acid residue of glutathione.

It is interesting to note that structures A and B, with a slight preference for B, were chosen by Pirie and Pinhey[6] on the basis of dissociation constants deduced from results obtained in the titration of glutathione.

BEN H. NICOLET

BUREAU OF DAIRY INDUSTRY,
U. S. DEPARTMENT OF AGRICULTURE

TRANSMISSION CHANGES IN ULTRA-VIOLET GLASSES DURING HIGH TEMPERATURE EXPOSURE TO LIGHT

THE recent keen interest in glasses transparent to ultra-violet radiation, and particularly the papers by Shrum, Patten and Smith[1] and by Stockbarger[2] in which are described certain phosphorescent and thermoluminescent properties of such glasses after exposure to ultra-violet light, suggest that some recent observations by the writers may be of interest to workers in this field.

It is well known that when some of these glasses are exposed to strong ultra-violet radiation, their transparency for the short wave-lengths is considerably decreased. It is also known that heating the solarized glasses restores them to their original condition.

In some recent experiments with several of the well-known brands the writers found that, if the specimens of glass were attached directly in contact with the hot tube of the mercury arc lamp and thus were kept at a high temperature (about 450° C.) during the ultra-violet exposure, there was no decrease in the short wave transmission, but instead, a marked increase. With one glass the shortest wave-length transmitted when new was 2535A. After solarization at atmospheric temperature, two feet from a quartz mercury arc, the transmitted spectrum was so shortened that 2620A was the low wave-length limit. When the glass, during exposure, was kept hot, the result was a very marked increase in transmission, so that wave-length 2460A was distinctly visible in the spectrogram of the transmitted radiation. This same result was obtained whether the glass had been previously solarized or not. In all cases the transmission spectra were photographed immediately after the ultra-violet exposure, the glass having cooled to room temperature. A condensed iron spark was used as the light source for testing the transmission.

All these specimens were then "annealed" in the dark at various temperatures, first at 200°, then successively at 300°, 350°, 400° and 450° C. After each annealing the glasses were cooled and their transmission spectra photographed. Even at 200° there was, in every case, indication of return toward the transmission of the original, new glass. This became more marked with increasing temperatures, until, after the 450° treatment, all had completely recovered the original condition.

On account of the fact that during the hot ultra-violet exposures there was only a line contact between the flat glass and the cylindrical lamp tube, the specimen was not uniformly heated. Examination (after cooling) with a low power polarizing microscope, between crossed nicols, showed severe strain in the glasses. This was also relieved by the subsequent annealing but had disappeared completely only after the last (450°) anneal.

Not all the ultra-violet glasses behaved in the way described. One in particular showed only a barely detectable decrease in transmission on low temperature exposure, and no change whatever after exposure in contact with the lamp tube.

C. C. NITCHIE
F. C. SCHMUTZ

RESEARCH DIVISION,
THE NEW JERSEY ZINC COMPANY

[5] Schlack and Kumpf, *Zeitschr. für physiol. Chem.*, 154: 125–70, 1926.

[6] *J. Biol. Chem.*, 84: 332, 1929.

[1] *Trans. Roy. Soc. Canada*, [3] 22: 433, 1928.

[2] *Tech. Engineering News*, December, 1929.

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Report on the Zoological Survey of India for the Years 1926 to 1929. Pp. lviii. Illustrated. Government of India, Central Publication Branch, Calcutta. 2s. 6d.

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